Annual WWW Technical Progress Report on the Global Data-Processing and Forecasting System 2003

Japan Meteorological Agency

1. Summary of highlights

(1) The utilization of SSM/I data was started in April 2003 for the global snow depth analysis in the land data assimilation system. (see 7.2.1).

(2) Assimilation of QuikSCAT/SeaWinds data for the global analysis was initiated in May 2003 (see 7.2.1).

(3) Assimilation of the BUFR-formatted high-density METEOSAT wind data for the global and other analyses was started in May 2003 (see 7.2.1).

(4) The cumulus parameterization scheme of GSM was modified in May 2003 (see 7.2.2).

(5) Direct assimilation of NOAA/ATOVS radiance data for the global analysis was initiated in May 2003 (see 7.2.1).

(6) A tropical cyclone bogussing for a four dimensional variational (4D-VAR) data assimilation system for the meso-scale analysis was implemented in June 2003 (see 7.3.2.1).

(7) A 4D-VAR data assimilation method was implemented for the regional analysis in June 2003 (see 7.3.1.1).

(8) A new physical process package was implemented in TYM in July 2003 (see 7.4.1.2).

(9) Assimilation of the TRMM/Microwave Imager (TMI) and SSM/I data for the meso-scale analysis was started in October 2003 (see 7.3.2.1).

(10) Numerical 120-day ensemble forecast for 3-month outlook was initiated in March 2003 (see 7.6).

(11) Numerical 210-day ensemble forecast for warm and cold seasons (June-July-August and December-January-February) outlook was started in September 2003 (see 7.6).

(12) Monthly averaged grid point value products of all ensemble members for the 120-day ensemble forecast has been disseminated at grid intervals of 2.5 degrees in the global area through the Tokyo Climate Center (TCC) since September 2003 (see 7.6).

(13) The global ocean data assimilation system (ODAS) was upgraded in February 2003 (see 7.4.5).

(14) The coupled atmosphere-ocean model for monthly El Niño outlook was upgraded in July 2003 (see 7.6.5).

(15) Verifications for extended- and long-range ensemble predictions are available on TCC, including the scores according to the Standard Verification System (SVS) for Long-Range Forecasts (LRF) (see 8.2 and 8.3).

2. Equipment in use at the Global-Data Processing and Forecasting System (GDFPS) Center in JMA

The Numerical Analysis and Prediction System (NAPS) was upgraded on March 1, 2001. Major features of the NAPS are listed in Table 1. JMA installed a new UNIX server (UNIX server 3) for the very short-range forecasting system on 1 March 2003.

Table 1 Major features of NAPS

Supercomputer		HITACHI-SR8000E1/80
Total node	80	
Total performance	768 Gflops	
Total capacity of memory	640 GB	
Data transfer rate	1.2 GB/s	
Storage disk capacity	4.8 TB	
Operating system	HI-UX/MPP	
UNIX server 1		HITACHI-3500/E540PS
Total node	6	
Total performance	215SPECint95	
Total capacity of memory	12 GB	
Storage disk capacity	389 GB	
Operating system	HI-UX/WE2	
UNIX server 2		HITACHI-3500/E540PS
Total node	4	
Total performance	151SPECint95	
Total capacity of memory	8 GB	
Storage disk capacity	354 GB	
Operating system	HI-UX/WE2	
UNIX server 3		HITACHI-EP8000 630 6C4
Total node	5	
Total performance	120SPECint_rate2000	
Total capacity of memory	40 GB	
Storage disk capacity	640 GB	
Operating system	AIX 5L	
Transmitting and receiving message server		HITACHI-3500/545RM
Performance	4.8 SPECint95	
Total capacity of memory	512 MB	
Storage disk capacity	12 GB	
Automated tape library		STORAGETEK Powderhorn 9310
Total storage capacity	80 TB	
Automated DVD-RAM library 1		HITACHI DT-DVDO-02
Total storage capacity	2.5 TB	

Automated DVD-RAM library 2		HITACHI DT-DVDO-02
Total storage capacity	3.1 TB	

3. Data and Products in use from GTS

3.1 Observations

The following observation reports are used in the data assimilation:

Table 2 Number of used observation reports

SYNOP/SHIP	51700/day
TEMP-A/PILOT-A	1700/day
TEMP-B/PILOT-B	1700/day
TEMP-C/PILOT-C	1100/day
TEMP-D/PILOT-D	1100/day
AIREP/AMDAR	141900/day
BUOY	12800/day
SATOB (SST)	4700/day
SATEM-A	11000/day
SATEM-C	10700/day
SATOB (WIND)	414100/day
SATOB (EUMETSAT)	319200/day
TOVS	82000/day
PROFILER	900/day
DMSP/SSMI	4431400/day

3.2 GRIB products

Following model products are used for internal reference and monitoring.

GRIB KWBC
GRIB ECMF
GRIB AMMC

4. Data input system

Data input is fully automated with an exception of the manual input of typhoon position, size and intensity data. They are used to generate typhoon bogus data for the global, regional and typhoon analyses.

5. Quality control system

Stage 1 Decoding

All the code forms of messages are checked against the WMO international code forms. When a form error is detected, some procedures are applied in order to extract as much information as possible.

Stage 2 Internal consistency check

Checks of climatological reasonability are performed for all types of data. The data enlisted as problematic data in the "black list" are rejected. Contents of the "black list" are occasionally revised based on results of non real-time quality control.

Consistency of consecutive positions is checked for reports from mobile stations such as ships, drifting buoys and aircraft. Consistency of consecutive reports and that among elements within a report are also checked for every surface station.

The vertical consistency is examined for TEMP and PILOT data using all parts of reports. The check items are:

(1) Icing of instruments;

(2) Temperature lapse rate;

(3) Hydrostatic relationship;

(4) Consistency among data at mandatory levels and those at significant levels; and

(5) Vertical wind shear.

Bias correction is applied to TEMP data which have large persistent biases from the first guess fields. Another bias correction scheme which checks consistency between the surface pressure observation and the sea surface pressure has been introduced since August 1998.

Checks of lapse rate for SATEM data are also performed using the mean virtual temperature estimated from the thickness.

Stage 3 Quality control with reference to the first guess

Gross error and spatial consistency are evaluated against the first guess in order to remove erroneous observations. The difference (D) of the observation value from the first guess value is compared with tolerance limits C_P and C_R. C_P is an acceptable limit and C_R is a rejection limit. When D is smaller than or equal to C_P, the datum is accepted for use in the objective analysis. When D is greater than C_R, it is rejected. When D is smaller than or equal to C_R and greater than C_P, the datum is further checked by interpolating the neighboring data to the location of the datum. If the difference between the datum and the interpolated value is not within a reasonable tolerance C_S, the datum is rejected.

These three tolerance limits vary according to the local atmospheric conditions which can be estimated by the first guess field. They are small if time tendency and horizontal gradient are small in the first guess field. The scheme is called "Dynamic QC" and is based on the idea that forecast errors would be small if the area is meteorologically calm and large if it is stormy.

Duplicate observation reports are frequently received through different communication lines. The most appropriate single report is chosen from these duplicate reports considering results from quality control of these reports.

All information on the quality of observational data obtained during the quality control procedure is archived in the Comprehensive Database for Assimilation (CDA). The CDA is used for non real-time quality control and global data monitoring activities.

6. Monitoring of the observing system

Non real-time quality monitoring of observations is carried out using observational data, real-time quality control information and the first guess archived in the CDA. The quality monitoring is made according to:

(1) Compilation of observational data rejected in the real-time quality monitoring;

(2) Calculation of statistics on the difference between observations and first-guess; and

(3) Statistical comparison of satellite data with collocated radiosonde data.

The above statistical information is effective in estimating systematic errors of observational data and also helpful to identify stations reporting suspect observations. If a station continuously reports suspect data for a long time, the data from the station are not used in the analysis.

The quality and availability of observational data are regularly issued as a monthly report entitled "JMA/NPD Global Data Monitoring Report". The statistics presented in the report are made according to the recommended procedures for the exchange of monitoring results by the Commission for Basic Systems (CBS). The report is sent to major Global Data-Processing and Forecasting System (GDPFS) centers as well as to the WMO Secretariat.

The RSMC Tokyo has been acting as a lead center for monitoring quality of land surface observations in Region II since March 1991. The statistical characteristics of availability and quality for sea level pressure observations of land surface stations in Region II are published in the semiannual report entitled "Report on the Quality of Surface Observations in Region II".

JMA also acts as a Principal Meteorological and Oceanographic Center (PMOC) of Data Buoy Cooperation Panel (DBCP). Quality of meteorological data for every observation element reported from ocean data buoys is monitored by time sequence maps comparing the data with the first guess field of the JMA Global Data Assimilation System. Sea surface and subsurface temperatures reported from buoys are also examined against climatic values and oceanographic analysis by JMA. Information on the buoys transmitting inferior quality data is sent to DBCP and other PMOCs over the Internet.

7. Forecasting system

JMA operationally performs four kinds of objective atmospheric analyses for the global, regional, meso-scale and typhoon forecast models. A three-dimensional variational (3D-VAR) scheme has been employed for the global and typhoon analyses since 26 September 2001. For the regional analysis, a four-dimensional variational (4D-VAR) scheme was implemented on 19 June 2003. For the mesoscale analysis, 4D-VAR has been employed since 19 March 2002. All analyses are made on model coordinates for surface pressure, geopotential height, vector winds, temperature and relative humidity.

Global analyses at 00UTC and 12UTC are performed twice. An early run analysis with a short cut-off time is performed to prepare initial conditions for operational forecast, and a cycle run analysis with a long cut-off time is performed to keep the quality of global data assimilation system. The early run analysis is not performed at 06 and 18UTC.

The specifications of the atmospheric analysis schemes are listed in Table 3.

Daily global SST analysis and daily global snow depth analysis are described in Table 4.1 and Table 4.2.

Table 3 Specifications of operational objective analysis

Cut-off time

(global)	2.5 hours for early run analyses at 00 and 12 UTC, 12.5 hours for cycle run analyses at 00 and 12 UTC, 7.33 hours for cycle run analyses at 06 and 18 UTC.
(regional)	3 hours for analyses at 00 and 12UTC, 8.33 hours for analyses at 06 and 18 UTC,
(meso-scale)	50 minutes for analyses at 00, 06, 12 and 18 UTC
(typhoon)	2.5 hours for analyses at 00 and 12UTC,

	1.5 hours for analyses at 06 and 18 UTC.

Initial Guess

(global)	6-hour forecast by GSM
(regional)	6-hour forecast by RSM
(meso-scale)	3-hour forecast by MSM
(typhoon)	6-hour forecast by GSM

Grid form, resolution and number of grids

(global)	Gaussian grid, 0.5625 degree, 640x320
(regional)	Lambert projection, 20km at 60N and 30N, 325x257, grid point (1,1) is at north-west corner and (200, 185) is at (140E, 30N)
(meso-scale)	Lambert projection, 10km at 60N and 30N, 361x289, grid point (1,1) is at north-west corner and (245, 205) is at (140E, 30N)
(typhoon)	same as global analysis

Levels

(global)	40 forecast model levels up to 0.4 hPa + surface
(regional)	40 forecast model levels up to 10 hPa + surface
(meso-scale)	40 forecast model levels up to 10 hPa + surface
(typhoon)	same as global analysis

Analysis variables

Wind, geopotential height (surface pressure), relative humidity and temperature

(Temperature is analyzed but not used as the initial condition for the regional and meso-scale model.)

Data Used

SYNOP, SHIP, BUOY, TEMP, PILOT, Wind Profiler, AIREP, SATEM, TOVS, ATOVS, SATOB and Australian PAOB.

Typhoon Bogussing

For typhoons over the western North Pacific, typhoon bogus data are generated to represent its accurate structure in the initial field of forecast models. They are made up of artificial geopotential height and wind data around a typhoon. The structure is asymmetric. At first, symmetric bogus data are generated automatically from the central pressure and 30kt/s wind speed radius of the typhoon. The asymmetric bogus data are generated by retrieving asymmetric components from the first guess field. Those bogus profiles are implanted into the first guess fields.

Initialization

Non-linear normal mode initialization with full physical processes is applied to the first five vertical modes.

Table 4.1 Specifications of SST analysis

Methodology	two-dimensional Optimal Interpolation scheme
Domain and Grids	global, 1x1 degree equal latitude-longitude grids
First guess	mean NCEP OI SST (Reynolds and Smith, 1994)
Data used	SHIP, BUOY and NOAA AVHRR SST data observed in past five days
Frequency	daily

Table 4.2 Specifications of Snow Depth analysis

Methodology	two-dimensional Optimal Interpolation scheme
Domain and Grids	global, 1x1 degree equal latitude-longitude grids
First guess	USAF/ETAC Global Snow Depth climatology (Foster and Davy, 1988)
Data used	SYNOP snow depth data and SSM/I snow cover data observed in past one day
Frequency	daily

JMA runs the Global Spectral Model (GSM0103; T213L40) twice a day (90-hour forecasts from 00 UTC and 216-hour forecasts from 12 UTC) and the Regional Spectral Model (RSM0103; 20kmL40) twice a day as well (51-hour forecasts from 00 and 12 UTC). The Meso-Scale Model (MSM0103; 10kmL40) is run four times a day (18-hour forecasts from 00, 06, 12 and 18 UTC) to predict severe weather phenomena. The Typhoon Model (TYM0103; 24kmL25) is also run four times a day (84-hour forecasts from 00, 06, 12 and 18 UTC) when any typhoons exist or are expected to be formed in the western North Pacific. Moreover JMA carries out 9-day Ensemble Prediction System (EPS) every day, 34-day EPS once a week for one-month outlook, 120-day EPS once a month for 3-month outlook and 210-day EPS twice a year for warm and cold seasons outlook. The basic features of the operational forecast models of JMA are summarized in Tables 6, 11 and 14.

An operational tracer transport model is run on request of national Meteorological Services in RA II or the International Atomic Energy Agency (IAEA) for RSMC support for environmental emergency response. A high-resolution regional transport model is experimentally run every day to predict volcanic gas spread.

The very short-range forecast of precipitation (VSRF) is operationally performed every half an hour. Details of the VSRF are described in 7.3.4.

Two ocean wave models, Global Wave Model and Coastal Wave Model are run operationally. The specifications of the models are described in Table 18.

The numerical storm surge model is run four times a day when a typhoon is approaching Japan. The specifications of the model are described in Table 19.

The Global Ocean Data Assimilation System (ODAS), whose specifications are described in Table 20, is operated.

The ocean data assimilation system in the North Pacific has been in operation since January 2001. The specifications of the model are described in Table 21.

The numerical sea ice model is run to predict sea ice distribution and thickness over the seas adjacent to Hokkaido twice a week in winter. The specifications of the model are given in Table 22.

The numerical marine pollution transport model is run in case of a marine pollution accident. The specifications of the model are described in Table 23.

7.1 System run schedule and forecast ranges

Table 5 summarizes the system job schedule of NAPS and forecast ranges. These jobs are executed in batch on the supercomputer and the UNIX server 1.

Table 5 The schedule of the NAPS (Numerical Analysis and Prediction System) operation

Time (UTC)	NAPS operation (Model forecast range)
0030 - 0120	12UTC decode, global cycle analysis
0030 - 0110	00UTC decode, meso-scale analysis
0110 - 0130	00UTC meso-scale forecast (0 - 18h)
0120 - 0210	18UTC decode, global cycle analysis
0120 - 0135	00UTC storm surge forecast (00h - 24h)
0230 - 0700	00UTC El Nino forecast, Ocean Data Assimilation
0230 - 0300	00UTC decode, global early analysis
0255 - 0320	18UTC decode, regional analysis
0300 - 0330	00UTC global forecast (00h - 90h)
0320 - 0345	00UTC decode, regional analysis
0330 - 0430	00UTC typhoon forecast (00 - 84h)
0345 - 0405	00UTC regional forecast (00h - 51h)
0410 - 0430	00UTC ocean wave forecast (00h - 90h)
0630 - 0710	06UTC decode, meso-scale analysis
0710 - 0730	06UTC meso-scale forocast (0 - 18h)
0720 - 0735	06UTC storm surge forecast (00h - 24h)
0730 - 0800	06UTC decode, typhoon analysis
0800 - 0900	06UTC typhoon forecast (00h - 84h)
1230 - 1320	00UTC decode, global cycle analysis
1230 - 1310	12UTC decode, meso-scale analysis
1310 - 1330	12UTC meso-scale forecast (0 - 18h)
1320 - 1410	06UTC decode, global cycle analysis
1320 - 1335	12UTC storm surge forecast (00h - 24h)
1430 - 1500	12UTC decode, global early analysis
1455 - 1830	12UTC medium-range ensemble forecast (0 – 216h)
1455 - 1520	06UTC decode, regional analysis
1500 - 1530	12UTC global forecast (00h - 90h)
1520 - 1545	12UTC decode, regional analysis
1530 - 1630	12UTC typhoon forecast (00 - 84h)
1545 - 1605	12UTC regional forecast (00h - 51h)
1610 - 1630	12UTC ocean wave forecast (00h - 90h)
1630 - 1715	12UTC global forecast (90h - 216h)
1715 - 1735	12UTC ocean wave forecast (90h - 216h)
1830 - 2135	12UTC one month forecast (34 days)
1830 - 1910	08UTC decode, meso-scale analysis
1910 - 1930	08UTC meso-scale forecast (0 - 18h)
1920 - 1935	18UTC storm surge forecast (00h - 24h)
1930 - 2000	18UTC decode, typhoon analysis
2000 - 2100	18UTC typhoon forecast (00h - 84h)

7.2 Medium-range forecasting system (3 - 9 days)

7.2.1 Data assimilation, objective analysis and initialization (Table 6)

A three-dimensional variational (3D-VAR) data assimilation method is employed for the analysis of the atmospheric state for the JMA Global Spectral Model (GSM). In the 3D-VAR, a statistical linear balance that includes dynamics in tropics and surface friction effects is globally satisfied. The analysis variables are relative vorticity, unbalanced divergence, unbalanced temperature, unbalanced surface pressure and the natural logarithm of specific humidity. In order to save the computational efficiency, an incremental method is adopted in which the analysis increment is evaluated at a lower horizontal resolution (T106) and then it is interpolated and added to the first guess field at the original resolution (T213).

A non-linear normal mode initialization with full physical processes is applied to the first five vertical modes. The effect of the atmospheric tide is considered by adding the model tidal tendency (constant) to the specific normal modes.

The operation of the global land surface analysis system (GLSAS) was started in April 2002 to provide initial conditions of land surface parameters for the T106 version of GSM used in the medium- and long- range forecast. The system consists of a land surface model (JMA-SiB) forced with atmospheric parameters and the JMA global snow depth analysis system. The GLSAS using daily SSM/I snow coverage was started in April 2003 to obtain an appropriate initial condition of land surface parameters.

The assimilation of QuikSCAT sea surface winds was started in May 2003. Positive impacts were found in typhoon track forecast experiments for July 2002.

A direct assimilation of ATOVS radiance data (HIRS/3, AMSU-A and AMSU-B of NOAA15 and NOAA16) on the JMA global 3D-VAR system was started in May 2003. To assimilate the ATOVS radiance data directly, the fast radiative transfer model RTTOV-6 developed at ECMWF was used in the system. Positive impacts were obtained on forecast skills of GSM, especially for short-range prediction.

7.2.2 Medium-range forecasting model

The specifications of the JMA Global Spectral Model (GSM) are listed in Table 6. The Arakawa-Schubert cumulus parameterization scheme was modified in May 2003. This change includes the introduction of the entrainment and detrainment effects between the cloud top and the cloud base in convective downdraft. This modification eliminated the cooling bias in the lower troposphere, and associated systematic error in geopotential height at lower troposphere was also decreased.

Table 6 Specifications of Global Spectral Model for 9-day forecasts

Basic equation	Primitive equations
Independent variables	Latitude, longitude, sigma-p hybrid coordinate and time
Dependent variables	Vorticity, divergence, temperature, surface pressure, specific humidity
Numerical technique	Euler semi-implicit time integration, spherical harmonics for horizontal representation and finite difference in the vertical
Integration domain	Global
Horizontal resolution	T213 (about 0.5625 degree Gaussian grid) 640x320
Vertical levels	40 (surface to 0.4hPa)
Forecast time	90 hours from 00UTC and 216 hours from 12UTC
Forecast phenomena	Synoptic disturbances and tropical cyclones

Orography	GTOPO30 30" x 30" dataset, spectrally truncated and smoothed.
Horizontal diffusion	Linear, second-order Laplacian
Moist processes	Prognostic Arakawa-Schubert cumulus parameterization + large-scale condensation
Radiation	Short-wave radiation computed every hour Long-wave radiation computed every three hours
Cloud water	Prognostic cloud water, cloud cover diagnosed from moisture and cloud
Gravity wave drag	Long-wave scheme for troposphere and lower stratosphere Short-wave scheme for lower troposphere
PBL	Mellor-Yamada level-2 closure scheme and similarity theory for surface boundary layer
Land surface	Simple Biosphere Model (SiB)
Surface state	SST anomaly added to seasonally changing climatological SST. Initial soil moisture, roughness length and albedo are climatological values. The analyzed snow depth is used for the initial value. Predicted values are used for the initial soil and canopy temperatures

7.2.3 Numerical weather prediction products for Medium-range forecast

The following model output products from GSM are disseminated through the JMA radio facsimile broadcast (JMH), GTS and RSMC Tokyo Data Serving System.

Table 7 Facsimile products for medium-range forecast

Content	Level (hPa)	Area (see Fig.1a)	Forecast Hours	Initial Time	Transmission Method
geopotential height, relative vorticity	500	O	96, 120, 144, 168, 192	12UTC	GTS
sea level pressure, rainfall amount	-	C	96, 120		radio facsimile

Table 8 Grid point value products (GRIB) for medium-range forecast

Contents	Level (hPa)	Area	Forecast Hours	Initial Time	Transmission Method
sea level pressure, rainfall amount	-	Global 2.5x2.5 Degree	96, 120	12UTC	GTS RSMC DSS
temperature, wind	surface				
geopotential height	1000				
geopotential height, temperature, wind	850, 700, 500, 300, 250, 200, 100, 70, 50, 30				
T-TD	850, 700				
sea level pressure, rainfall amount	-		144, 168, 192		
temperature, wind	Surface				
	1000				
geopotential height, temperature, wind	850, 700, 500, 300, 200				
T-Td	850, 700				
sea level pressure, rainfall amount	-	Global	96, 108, 120	12UTC	RSMC DSS

temperature, wind, relative humidity	surface	1.25x1.25 Degree	132, 144, 156, 168, 180, 192		
geopotential height, temperature, wind, relative humidity, vertical p-velocity	1000, 925, 850, 700, 600, 500, 400, 300,				
geopotential height, temperature, wind	250, 200, 150, 100, 70, 50, 30, 20, 10				
relative vorticity	500				
T-TD	850, 700				

7.2.4 Operational techniques for application of GSM products

Atmospheric angular momentum (AAM) functions are computed from analyzed and forecasted global wind and surface pressure data and sent to NCEP/NOAA.

7.2.5 Medium-range Ensemble Prediction System (EPS) (9-day)

The numerical weather prediction model applied for the EPS is a low-resolution version (T106) of the GSM. Thus, the dynamical framework and all physical processes are identical with those of the high-resolution GSM (T213) mentioned at 7.2.2 except for the horizontal resolution. The atmospheric initial condition for the control run is prepared by interpolating the T213 analysis. The initial condition for a land surface model is generated by running the land surface model with external forcing of T213 atmospheric four-dimensional data assimilation (4DDA) as well as assimilating snow depth analysis.

Table 9 Specifications of 9-day Ensemble Prediction System

Integration domain	Global, surface to 0.4hPa
Horizontal resolution	T106 (about 1.125 degree Gaussian grid) 320x160
Vertical levels	40 (surface to 0.4hPa)
Forecast time	216 hours from 12UTC
Ensemble size	25 members
Perturbation generator	Breeding of Growing Mode (BGM) method (12 independent breeding cycles in 12 hours periods)
Perturbed area	Northern hemisphere and tropics (20S-90N)

7.2.5.1 Numerical weather prediction products for Medium-range Ensemble Prediction

The following model output products from Medium-range Ensemble Prediction are disseminated through RSMC Tokyo Data Serving System.

Table 10 Grid point value products (GRIB) for Medium-range Ensemble Prediction

Contents	Level (hPa)	Area	Forecast Hours	Initial Time	Transmission Method
sea level pressure	-	Global 2.5x2.5 Degree	Every 6 hours from 0 to 192 hours	12UTC	RSMC DSS
geopotential height	1000, 500				
temperature	850				
wind	850, 250				

* Above GPVs are ensemble mean and standard deviation derived from ensemble members.

7.3 Short-range forecasting systems

7.3.1 Short-range forecasting system (0-51 hours)

7.3.1.1 Data assimilation, objective analysis and initialization

A regional 4D-VAR system was implemented on 19 June 2003 for the analysis of the atmospheric state for the JMA Regional Spectral Model (RSM). The architecture of the system is almost the same as the meso-scale 4D-VAR (see 7.3.2.1), except that the resolution of the inner-loop model is 40km and a six-hour assimilation window is employed. Initial and lateral boundary conditions for 4D-VAR are derived from GSM forecasts.

7.3.1.2 Regional Spectral Model (RSM)

Table 11 Specifications of Regional Spectral Model (RSM0103)

Basic equation	Primitive equations
Independent variables	x-y coordinate on a Lambert projection plane and sigma-p hybrid coordinate
Dependent variables	Wind components of x-y direction, virtual temperature, natural log of surface pressure and specific humidity
Numerical technique	Euler semi-implicit time integration, double Fourier for horizontal representation and finite difference in the vertical
Projection and grid size	Lambert projection, 20km at 60N and 30N
Integration domain	East Asia centering on Japan, 325 x 257 transform grid points
Vertical levels	40 (surface to 10hPa)
Forecast time	51 hours from 00, 12UTC
Forecast phenomena	Meso-beta scale disturbances
Initial	First guess is 3-9 hours forecast of RSM initialized 6 hour earlier
Data cutoff	3 (9)-hour cutoff for 00, 12 (06, 18) UTC
Lateral boundary	0-51 hours forecast by GSM runs
Orography	Envelope orography. Orography is smoothed and spectrally truncated.
Horizontal diffusion	Linear, second-order Laplacian.
Moist processes	Large scale condensation + Prognostic Arakawa-Schubert convection scheme + middle level convection + shallow convection
Radiation (short-wave)	Every hour
(long-wave)	Every hour
Cloudiness	Diagnosed from relative humidity, maximum overlap
Gravity wave drag	Short-wave scheme for lower troposphere is included.
PBL	Mellor-Yamada level-2 closure scheme for stable PBL, non-local scheme for unstable PBL, and similarity theory for surface boundary layer
Land surface	Ground temperature is predicted with the use of four levels in the ground. Evaporability depends on location and season.
Surface state	Observed SST (fixed during time integration) and sea ice distribution. Evaporability, roughness length, albedo are climatological values. Snow cover over Japan is analyzed every day.

7.3.1.3 Numerical weather prediction products

The following model output products from GSM are disseminated through the JMA radio facsimile broadcast (JMH), GTS and RSMC Tokyo Data Serving System. No products from RSM are disseminated through these systems.

Table 12 Facsimile products for short-range forecast

Contents	Level (hPa)	Area (see Fig.1)	Forecast Hours	Initial Time	Transmission Method
geopotential height, relative vorticity	500	A'	0	00UTC 12UTC	GTS
vertical p-velocity	700				
temeprature, wind	850				
geopotential height, relative vorticity	500		24, 36		
sea level pressure, rainfall amount	-				
Temperature	500				
T-Td, vertical p-velocity	700				
temperature, wind	850				
sea level pressure, rainfall amount	-	C	24, 48, 72		
geopotential height, relative vorticity	500		48, 72		
geopotential height, temperature, T-Td	850		0		
geopotential height, temperature, T-Td	700				
geopotential height, temperature	500				
geopotential height, temperature, wind	300				
geopotential height, temperature, wind	200	Q	0		
geopotential height, temperature, wind	250		0, 24		
geopotential height, temperature, wind	500		24		
geopotential height, temperature	500	D	0	12UTC	
stream line	200	-	0, 24, 48		
stream line	850				
geopotential height, temperature	500	C	0	00UTC 12UTC	radio facsimile
geopotential height, temperature, T-Td	850				
sea level pressure, rainfall amount	-		48,72		

Table 13 Grid point value products (GRIB) for short-range forecast

Contents	Level (hPa)	Area	Forecast Hour	Initial Time	Transmission Method
sea level pressure	-	Global 2.5x2.5 degree	0	00UTC 12UTC	GTS RSMC DSS
temperature, wind, T-TD	Surface				
geopotential height, temperature, wind	1000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10				
T-Td	1000, 850, 700, 500, 400, 300 (00UTC) 850, 700 (12UTC)				
sea level pressure, rainfall amount	-		24, 48, 72	00UTC 12UTC	
temperature, wind	Surface				

geopotential height, temperature, wind	850, 700, 500, 300, 250, 200, 100, 70, 50, 30				
T-TD	850, 700				
sea level pressure, rainfall amount	-	20S-60N 80E-160W 2.5x2.5 degree	0, 6, 12, 18, 24, 30, 36, 48, 60, 72	00UTC 12UTC	GTS RSMC DSS
temperature, wind, T-TD	Surface				
geopotential height, temperature, wind, T-TD, vertical p-velocity	850, 700				
geopotential height, temperature, wind, T-TD, relative vorticity	500				
geopotential height, temperature, wind	300, 250, 200, 150, 100				
sea level pressure, rainfall amount	-	20S-60N 80E-160W 1.25x1.25 degree	0, 6, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, 72, 78, 84		
temperature, wind, T-TD	Surface				
geopotential height, temperature, wind, T-TD, vertical p-velocity	925, 850, 700				
geopotential height, temperature, wind, T-TD	500, 400, 300				
geopotential height, temperature, wind	250, 200, 150, 100, 70, 50 30, 20				
relative vorticity	500				
vorticity potential, stream function	850, 200				
sea level pressure, rainfall amount	-	Global 1.25x1.25 degree	0, 6, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, 72, 78, 84	00UTC 12UTC	RSMC DSS
temperature, wind, relative humidity	Surface				
geopotential height, temperature, wind, relative humidity, vertical p-velocity	1000, 925, 850, 700, 600, 500, 400, 300,				
geopotential height, temperature, wind	250, 200, 150, 100, 70, 50, 30, 20, 10				
relative vorticity	500				
vorticity potential, stream function	850, 200				

7.3.1.4 Operational techniques for application

The Kalman-filtering technique and the Neural-network technique are applied to grid point values predicted by RSM to derive forecast elements. The Kalman-filtering technique is used to derive probability of precipitation, three-hourly precipitation amount, surface air temperature and surface wind. The Neural-network technique is introduced to derive three-hourly weather category, minimum humidity, probability of heavy precipitation and probability of thunderstorm. A new technique for estimating the maximum precipitation in each sub-divided forecasting district derived from area mean precipitation was put into operation. A new technique for estimating the maximum wind speed in three-hour interval at each surface station was put into experimental operation in September 2002.

7.3.2 Short-range forecasting system (0 – 18 hours)

7.3.2.1 Data assimilation, objective analysis and initialization

A four-dimensional variational (4D-VAR) data assimilation method has been employed since 19 March 2002 for the analysis of the atmospheric state for the JMA Meso-Scale Model (MSM) with a three-hour assimilation window. Radar-AMeDAS precipitation data (see 7.3.4.1) in addition to conventional data is used for assimilation. The analysis variables are surface pressure, temperature, unbalanced wind and specific humidity. In order to save the computational efficiency, an incremental method is adopted in which the analysis increment is evaluated at a lower horizontal resolution (20km) and then it is interpolated and added to the first guess field at the original resolution (10km).

Non-linear normal mode initialization (NNMI) with full physical processes is applied to the first five vertical modes. Initial and lateral boundary conditions for 4D-VAR are derived from RSM forecasts.

A new tropical cyclone bogussing method has been implemented since June 2003. In the new boggussing method, the following procedures are employed; 1) a bogus structure is made with the same method as the GSM bogussing. 2) pseudo observational data are made according to the 3D-structures of wind and pressure field determined from the bogus structure. 3) 4D-VAR analysis is conducted with the pseudo observational data so that the dynamical consistency in the analysis field is preserved.

An assimilation system of precipitation data and TPW data retrieved from TMI and SSM/I was implemented in October 2003. Since TPW can be retrieved in the rain-free area, it is complement to the retrieved precipitation field. The use of TPW improved the water vapor field and it brought positive impact on the precipitation prediction.

7.3.2.2 Meso-Scale Model (MSM)

The model specifications are identical to those of RSM (Table 11) except for the followings:

Table 14 Specifications of Meso-Scale Model (MSM0103)

Projection and grid size	Lambert projection, 10km at 60N and 30N
Integration domain	Japan, 369 x 289 transform grid points
Vertical levels	40 (surface to 10hPa)
Forecast time	18 hours from 00, 06, 12, 18 UTC
Forecast phenomena	severe weather
Initial	First guess is 0-6 hour forecast of MSM initialized 6 hour earlier
Data cutoff	50-minute cutoff
Lateral boundary	06-24 (12-30) hour forecast by RSM initialized of 6 (12) hours earlier for 06, 18 (00, 12) UTC forecast
Orography	Mean orography. Orography is smoothed and spectrally truncated.
Surface state	Observed SST (fixed during time integration) and sea ice distribution. Evaporability, roughness length, albedo are climatological values. Snow cover over Japan is analyzed every day.

7.3.2.3 Numerical weather prediction products

Products from MSM are disseminated through neither JMH nor GTS.

7.3.2.4 Operational techniques for application

Significant weather charts and prognostic cross section charts for domestic aviation forecast are produced 4 times a day (00, 06, 12 and 18 UTC).

Weather forecast guidance for the short-time-range Terminal Aerodrome Forecast (TAF-Short) using the Kalman Filtering technique is disseminated 4 times a day. Forecast elements are hourly maximum wind speed and its direction, cloud amount, minimum ceiling, minimum visibility and weather category up to 15 hours.

The Kalman-filtering technique is experimentally applied to grid point values predicted by MSM to derive forecast elements such as maximum precipitation in each sub-divided forecasting district and maximum wind speed at three-hour intervals at each surface station.

7.3.3 The Hourly Wind Analysis in Lower Atmosphere

A multivariate three-dimensional optimum interpolation (3D-OI) scheme on model levels is employed to analyze wind in lower atmosphere. Wind profiler data at every hour is used as an observational data, which is obtained from the Wind Profiler Network and Data Acquisition System (WINDAS) of JMA. The Doppler radar data at airports are also used. The latest MSM forecast is used as a first guess. The analysis area is limited in and around Japan.

7.3.4 Very short-range forecasting system (0-6 hours)

7.3.4.1 Method of data processing

Using radar reflectivity factors estimated from with the power scattered by rain particles at 20 digitized ground-based radar sites and precipitation observations by AMeDAS (Automated Meteorological Data Acquisition System, a nationwide network of more than 1300 rain-gauges of JMA) and nearly 4,000 rain-gauges belonging to other organizations, one-hour precipitation data over Japan, called Radar-AMeDAS precipitation, are analyzed every half an hour with a 2.5km resolution. Radar reflectivity factors are translated into rainfall intensities with a Z-R relationship and accumulated to one-hour precipitation. The analysis of precipitation at each radar is made by calibrating the accumulated radar one-hour precipitation with the rain-gauge observations. The Radar-AMeDAS precipitation is the composite of analyzed precipitation of all the radars. An initial field for a linear extrapolation forecast is the composite of calibrated rainfall intensities.

The linear extrapolation forecast and the precipitation forecast from the Meso-Scale Model (MSM; see 7.3.2.2) are merged into the final very-short-range precipitation forecast. The merging weight of MSM forecast is nearly zero at one hour forecast and gradually increased with forecast time to a value determined from the relative skill of the MSM forecasts.

7.3.4.2 Model

Table 15 Specifications of linear extrapolation model

Forecast process	Linear extrapolation
Physical process	Topographic enhancement and dissipation
Motion vector	Motion of a precipitation system is evaluated by the cross correlation method
Time step	10 minutes
Grid form	Oblique conformal secant conical projection
Resolution	5km
Number of grids	320 x 720
Initial	Calibrated radar echo intensities
Forecast time	Up to six hours from each initial time (every 30 minutes = 48 times/day)

7.3.4.3 Products

The basic products of the very short-range forecasting system are: (a) composite radar echo (echo intensity and echo top height), (b) estimated one-hour precipitation distributions and (c) one-hour precipitation forecasts up to six hours. These products are provided at about 20 minutes after the analysis time to support the local weather offices that issue weather warnings for heavy precipitation.

7.4 Specialized forecasts

7.4.1 Typhoon forecasting system

7.4.1.1 Objective analysis and initialization

The analysis for numerical typhoon track prediction is made using the global analysis model. After symmetric typhoon bogus data is implanted into the analysis field with asymmetric components preserved, nonlinear normal mode initialization with full physics is applied to the first five vertical modes.

7.4.1.2 Typhoon model (TYM)

The model specifications are similar to those of RSM (Table 11). A new physical process package, including a prognostic cloud water scheme, a modified cumulus parameterization and a new radiation process, was introduced into TYM in July 2003. In order to suppress the over-prediction of typhoon intensity, the roughness length on sea surface, and the ratio of the bulk exchange coefficients of heat and moisture to that of momentum, were also changed so that the heat and moisture fluxes on sea surface were reduced.

Table 16 Specifications of Typhoon Model (TYM)

Independent variables	x-y coordinate on a Lambert (Mercator) projection plane for the target typhoon north (south) of 20N and sigma-p hybrid coordinate
Projection and grid size	Lambert (Mercator) projection, 24 km at the typhoon center when center of the target typhoon is north (south) of 20N.
Integration domain	Center of domain is set at median of expected track of the target typhoon in the western North Pacific, 271x271 transform grid points
Vertical levels	25 (Surface to 17.5hPa)
Forecast time	84 hours from 00, 06, 12, 18UTC, maximum two runs for each initial time
Forecast phenomena	Typhoons
Initial	Global analysis using 6-hour forecast by GSM as a guess field with data cut-off time of 2.5 (1.5) hours for 00, 12 (06, 18) UTC initial.
Lateral boundary	0-84 hour forecast by GSM for 00, 12 UTC initial 6-90 hour forecast by GSM initialized 6 hours earlier for 06, 18 UTC initial
PBL	Mellor-Yamada level-2 closure scheme for stable PBL, and similarity theory for surface boundary layer
Surface state	Observed SST fixed during time integration climatological evaporability, roughness length and albedo
Typhoon bogussing	Symmetric vortex generated using a manually analyzed central pressure and the radius of 30kt winds with gradient-wind balance assumed in the free atmosphere,

Ekman-frictional inflow and compensating outflow added in PBL and in upper levels, respectively. The vortex is blended with the global analysis in combination with asymmetric components taken from TYM's own forecasts, when available.

7.4.1.3 Numerical weather prediction products

The following products from the output of GSM and TYM are disseminated through GTS.

Table 17 Numerical weather prediction products for typhoon forecast

Contents	Level (hPa)	Area	Forecast Hours	Initial Time	Transmission Method
Center position and changes of intensity parameters from the initial time by GSM	-	Eq. - 60N 100E-180E	06, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, 72, 78, 84	00UTC 12UTC	GTS
Center position and changes of intensity parameters from the initial time by TYM	-	Eq. - 60N 100E-180E	06, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, 72, 78	00UTC 06UTC 12UTC 18UTC	GTS

7.4.2 Environmental Emergency Response System

JMA is a Regional Specialized Meteorological Center (RSMC) for Environmental Emergency Response in RA II for preparation and dissemination of transport model products on exposure and surface contamination of accidentally released radioactive materials.

The transport model adopts a Lagrangian method. In the model, many tracers are released in time and location according to information on pollutant emissions. Effects for three-dimensional advection and horizontal and vertical diffusions, dry and wet depositions and radioactive decay are computed from 3-hourly model-level outputs of the high resolution global model (T213L40). Main products of the RSMC are trajectories, time integrated low-level concentrations and total deposition up to 72 hours.

A high-resolution regional transport model is experimentally operated to predict volcanic gas spread from Miyakejima Island, an active volcano of Japan. The concentration of SO_2 is predicted up to 36 hours every day (00UTC initial). The atmospheric state is provided by the RSM forecast 3-hourly.

7.4.3 Ocean wave forecasting system

7.4.3.1 Models

JMA operates two numerical wave modes; Global Wave Model (GWM) and Coastal Wave Model (CWM). Both models are classified into the third generation wave model.

Table 18 Specifications of ocean wave prediction models

Model name	Global Wave Model	Coastal Wave Model
Model type	Spectral model (third generation wave model)	
Spectral component	400 components (25 frequencies from 0.0375 to 0.3Hz and 16 directions)	
Grid form	Equal latitude-longitude grid on spherical coordinate	
Grid size	1.25deg. x 1.25deg. (288x121)	0.1deg. x 0.1deg. (400x400)
Integration domain	Global 75N-75S, 0E-180-1.25W	Coastal sea of Japan 55N-15N, 115E-155E
Time step	30 minutes	5 minutes
Forecast time	90 hours from 00UTC 216 hours from 12UTC	84 hours from 00, 12UTC
Boundary condition	-	Global Wave Model
Initial condition	Hindcast	
Wind field	Global Spectral Model (GSM)	Regional Spectral Model (RSM) with the supplement of GSM
	Bogus gradient winds (for typhoons in the western North Pacific)	

7.4.3.2 Numerical wave prediction products

The grid point values (GPVs) of the wave models are disseminated to domestic users. The GPVs of GWM are also available in the RSMC Tokyo Data Serving System of JMA.

The model products are also reported to the Marine Pollution Emergency Response Authority (MPEROA) within the Marine Pollution Emergency Response Support System (MPERSS).

7.4.4 Storm surge forecasting system

7.4.4.1 Model

JMA operates the numerical storm surge model and its specifications are given in Table 19.

Table 19 Specifications of the numerical storm surge model

Basic equations	Two dimensional shallow water equations
Numerical technique	Explicit finite difference method
Integration domain	Coastal area of Japan (122.5- 143.1E, 23.5- 42.1N)
Grid size	1 minute(longitude) x 1 minute(latitude)
Boundary conditions	Modified radiation condition at open boundaries and zero normal flows at coastal boundaries
Forcing data	Wind and pressure fields derived from parametric formulae with typhoon position and intensity analysis

7.4.4.2 Numerical storm surge prediction products

Time series of predicted storm surge and predicted tidal level, and predicted highest tide for about 200 ports are disseminated to local meteorological observatories, and are used for issuing storm surge advisories and warnings.

7.4.4.3 Operational techniques for application of storm surge prediction products

Considering the error of typhoon forecast track, storm surges for possible 5 tracks are predicted.

7.4.5 Global Ocean data assimilation system

A global ocean data assimilation system (ODAS) was upgraded in February 2003. Major changes of the ODAS are introduction of the 3D-VAR analysis, adoption of the Incremental Analysis Update scheme, and addition of salinity and sea surface height as the assimilated variables. Its specifications are shown in Table 20.

Table 20 Specifications of the Global Ocean Data Assimilation System

Basic equation	Primitive equations, rigid lid
Independent variables	Lat-lon coordinate and z vertical coordinate
Dependent variables	u, v, T, S
Numerical technique	Finite difference both in the horizontal and in the vertical
Grid size	2.5 degree (longitude) x 2.0 degree (latitude, smoothly decreasing to 0.5 degree toward the equator) grids
Vertical levels	20 levels
Integration domain	Global (from 66N to 80S, toward poles from 60N and 60S, prognostic fields are nudged to climatology)
Forcing data	Heat, water, and momentum fluxed are driven from the operational global 4DDA
Observational data	Sea surface and sub surface temperature and salinity, sea surface height
Operational runs	Two kinds of run, final run and early run, with cut-off time of 30 days and 1 day, respectively, for ocean observation data

The output of ODAS is fed to an interactive graphic tool for the analysis of tropical ocean status. Some figures based on ODAS outputs are included in the Monthly Ocean Report and in the Monthly Report on Climate System of JMA, and provided through the DDB homepage of JMA. The data are also used as the oceanic initial conditions for the JMA coupled ocean-atmosphere model.

7.4.6 Ocean Data Assimilation System in the North Pacific Ocean

7.4.6.1 Model

The ocean data assimilation system in the North Pacific has been in operation since January 2001, to represent the ocean structure such as the Kuroshio in the mid/high latitudes of the North Pacific with the following specifications.

Table 21 Specifications of the ocean data assimilation system in the North Pacific Ocean

Basic equation	Primitive equations, rigid lid
Independent variables	Latitudinal and longitudinal in horizontal coordinate, z in vertical coordinate
Dependent variables	Ocean current components of latitudinal and longitudinal direction, temperature and salinity (nudged to climatology deeper than 2,000 m)
Numerical technique	Finite difference both in the horizontal and in the vertical, nudging with observational temperature, estimated temperature and salinity from sea surface height
Grid size	Variable horizontal resolution, 1/4 x 1/4 degrees adjacent to Japan between 23N and 45N west of 180E, smoothly increasing to 0.5 degree in latitude and to 1.5 degrees in longitude
Time step	10 minutes
Vertical levels	21 levels
Integration domain	North Pacific between 13N and 55N from 120E to 110W
Forcing data	Ocean currents are driven by operational daily wind stress

Observational data	Sea surface height, sea surface and subsurface temperature

7.4.6.2 Products of the ocean data assimilation system

The output of this system is monthly averaged and provided in a printed matter, "Monthly Ocean Report" of JMA, and on a web site, NEAR-GOOS RRTDB (http://goos.kishou.go.jp).

7.4.7 Sea ice forecasting system

7.4.7.1 Model

JMA issues information on the state of sea ice in the seas adjacent to Japan. A numerical sea ice model has been run to predict sea ice distribution and thickness in the seas adjacent to Hokkaido (mainly the southern part of the Sea of Okhotsk), twice a week in winter since December 1990 (see Table 22).

Table 22 Specification of the numerical sea ice prediction model

Dynamical processes	Viscous-plastic model(MMD/JMA,1993. wind and sea water stress to sea ice, Coriolis' force, force from gradient of sea surface and internal force are considered)
Physical processes	Heat exchange between sea ice, atmosphere and sea water
Dependent variables	Concentration and thickness
Grid size and time step	12.5km and 6 hours
Integration domain	Seas around Hokkaido
Forecast time	168 hours from 00UTC twice a week
Initial	Concentration analysis derived from GMS and NOAA satellite imagery and thickness estimated by hindcast

7.4.7.2 Numerical sea ice prediction products

The grid point values (GPVs) of the numerical sea ice model are disseminated to domestic users. The sea ice conditions for the coming seven days predicted by the model are broadcast by JMH twice a week.

7.4.8 Marine pollution forecasting system

7.4.8.1 Model

JMA operates the numerical marine pollution transport model in case of a marine pollution accident. Its specifications are shown in Table 23. The ocean currents for the input data of the model are derived from the result of the ocean data assimilation system in the North Pacific Ocean.

Table 23 Specifications of the marine pollution transport model

Area	Western North Pacific
Grid size	2 - 30km (variable)
Model type	3-dimensional parcel model
Processes	Currents caused by ocean currents, sea surface winds and ocean waves Turbulent diffusion Chemical processes (evaporation, emulsification)

7.5 Extended-range forecasting system

7.5.1 Data assimilation and Model

An extended-range ensemble prediction system is carried out as an extension of the Medium-range Ensemble Prediction System described in 7.2.5. Data assimilation, objective analysis, initialization and the model are common to those of the medium-range ensemble prediction system. For the lower boundary condition of the model, SST anomalies are fixed during the 34-day time integration. Soil moisture, temperature and snow depth are predicted by the model, and their initial states are provided by the land data assimilation system.

7.5.2 Methodology

An ensemble consists of 26 members per week by extending 13 member runs of the medium-range ensemble prediction system on consecutive two days up to 34 days. Thus, initial perturbation is prepared with a combination of a breeding of growing mode (BGM) method and a lagged average forecast (LAF) method.

7.5.3 Numerical prediction products

A model systematic bias was estimated as an average forecast error which was calculated from hindcast experiments for years from 1984 to 1993. The bias is removed from forecast fields, and grid point values are processed to produce several forecast materials such as ensemble mean, spread, and so on.

The grid point value products from extended-range ensemble prediction system disseminated through the GTS and the Tokyo Climate Center (TCC) Web site (http://cpd2.kishou.go.jp/tcc) are shown in Table 24. The map products disseminated through TCC are shown in Table 25.

Table 24 Grid point value products (GRIB) for extended–range forecast through GTS and TCC

<table>
<tr><th colspan="2">Contents</th><th>Level (hPa)</th><th>Area</th><th>Initial time & Forecast Time</th></tr>
<tr><td rowspan="7">Ensemble mean value of forecast members averaged for 7 days forecast time range</td><td>Sea level pressure, rainfall amount</td><td>-</td><td rowspan="4">Global 2.5x2.5 degree</td><td rowspan="7">Initial time : 12UTC of 2 days of the week (Wednesday & Thursday)

Forecast time : 2-8, 9-15, 16-22, 23-29 days from later initial time</td></tr>
<tr><td>Temperature, RH, wind (u, v)</td><td>850</td></tr>
<tr><td>Geopotential height,</td><td>500,100</td></tr>
<tr><td>Wind (u, v)</td><td>200</td></tr>
<tr><td>Sea level pressure anomaly</td><td>-</td><td rowspan="7">Northern Hemi-sphere 2.5x2.5 degree</td></tr>
<tr><td>Temperature anomaly</td><td>850</td></tr>
<tr><td>Geopotential height anomaly</td><td>500,100</td></tr>
<tr><td rowspan="3">Spread (Standard deviation) among time averaged ensemble member forecasts</td><td>Sea level pressure</td><td>-</td><td rowspan="4">Forecast time : 2-8, 9-15, 16-22, 23-29, 2-15, 16-29, 2-29 days from later initial time</td></tr>
<tr><td>Temperature</td><td>850</td></tr>
<tr><td>Geopotential height</td><td>500</td></tr>
<tr><td colspan="2">large anomaly index * of geopotential height</td><td>500</td></tr>
</table>

* large anomaly index is defined as {(number of members whose anomaly is higher than 0.5xSD) – (number of members whose anomaly is lower than – 0.5xSD)}/{number of members} at each grid point, where SD is defined as observed climatological standard deviation.

Table 25 Map products for extended–range forecast through TCC

<table>
<tr><th></th><th>Forecast time</th><th>Parameter</th></tr>
<tr><td>Ensemble mean</td><td rowspan="2">Day 2–8, day 9–15, day 16–29, day 2–29 averages</td><td>Geopotential height and anomaly at 500hPa,temperature and anomaly at 850hPa,sea level pressure and anomaly</td></tr>
<tr><td>Spread (Standard deviation) among time averaged ensemble member forecasts</td><td>Geopotential height at 500hPa</td></tr>
</table>

Large anomaly index*		
Time-longitude cross section	7-day running mean	Velocity potential at 200hPa averaged in the equatorial region (from 5N to 5S)
Time sequence		Several circulation indices

* large anomaly index is defined as {(number of members whose anomaly is higher than 0.5xSD) – (number of members whose anomaly is lower than – 0.5xSD)}/{number of members} at each grid point, where SD is defined as observed climatological standard deviation.

7.5.4 Operational technique for an application of extended-range forecast

Objective guidance products of forecast elements such as the surface temperatures (monthly mean, weekly mean), precipitation amounts (monthly total), sunshine durations (monthly total), and snowfall amounts (monthly total) are derived by the Perfect Prognosis Method (PPM) technique. A clustering method is applied and cluster-averaged fields are disseminated to local meteorological observatories.

7.6 Long-range forecasting system

7.6.1 The 120-day ensemble prediction system (EPS) for 3-month outlook

The 120-day long-range EPS for 3-month outlook is operated once a month by the 25th day. The numerical prediction model applied for the long-range EPS is an old and low-resolution version (T63) of GSM (Table 26). Thus, cumulus parameterization and associated initialization schemes are different from those of the current GSM (GSM0305) mentioned at 7.2 in addition to the horizontal resolution. For the lower boundary condition of the model, initial SST anomalies are fixed during the 120-day time integration. Soil moisture, temperature and snow depth are predicted by the model, and their initial states are provided by the land data assimilation system.

An ensemble consists of 31 members including a control run. The initial condition for the control run is prepared in the same way as those for the medium-range EPS. Their initial perturbations in the atmosphere are prepared with a Singular Vector (SV) Method.

Table 26 Specifications of 120-day Ensemble Prediction System

Atmospheric model	GSM0103
Integration domain	Global, surface to 0.4hPa
Horizontal resolution	T63 (about 1.875º Gaussian grid 192by96 ~180km)
Vertical levels	40 (surface to 0.4hPa)
Forecast time	2880 hours from 12UTC
Ensemble size	31 members
Perturbation generator	Singular Vector (SV) Method
Perturbed area	Northern hemisphere and tropics (20S-90N)

7.6.2 Numerical prediction products for 120-day ensemble prediction

A model systematic bias was estimated as an average forecast error, which was calculated from hindcast experiments for 18 years from 1984 to 2001. The bias is removed from forecast fields, and grid point values are processed to produce several forecast materials such as ensemble mean, spread, and so on.

The following model output products from 120-day ensemble prediction are disseminated through the Tokyo Climate Center (TCC) Web site (http://cpd2.kishou.go.jp/tcc).

Table 27 Grid point value products (GRIB) for 120-day prediction through TCC

Contents		Level (hPa)	Area	Initial time & Forecast Time
Ensemble mean value of forecast members averaged for every each month and three months during forecast time range	Rainfall amount, surface temperature at 2m, sea surface temperature and their anomalies	-	Global 2.5x2.5 degree	Initial time : 12UTC around 15^{th} day in each month Forecast time : Every each month and three months average
	Temperature	850		
	Geopotential height	500		
	Wind (u, v) and their anomalies	850,200		
	Sea level pressure	-		
	Temperature anomaly	850	Northern Hemi-sphere 2.5x2.5 degree	
	Geopotential height anomaly	200		
	Sea level pressure anomaly	-		
	Temperature	850		
	Geopotential height	500		
	Wind (u, v)	850,200		
	Sea level pressure	-		

7.6.3 The 210-day ensemble prediction system (EPS) for warm and cold seasons outlook

The 210-day long-range EPS for warm and cold seasons outlook is operated twice a year by the 25^{th} day in February and September. The 210-day ensemble prediction system is carried out as an extension of the 120-day ensemble prediction system except that separately predicted SST anomalies are prescribed as a boundary condition (See 7.6.4). Note that 180-day and 150-day EPSs are also conducted in March, April and October for warm and cold season outlook in the same way as the 210-day EPS.

7.6.4 Methodology for the prediction of global SST anomalies for 210-day EPS

A two-tiered way is adapted for the 210-day EPS; first, global SST anomalies are predicted, then the integration of the atmospheric model (GSM) is performed during 210 days.

Initial SST anomalies are assumed to persist for first two months of the 210 days. To predict global SST anomalies for the last two months of the 210 days, the Niño3 (eastern-equatorial Pacific) SST anomaly is predicted with the El Niño prediction model (atmosphere-ocean coupled model) and corrected by the MOS (Model Output Statistics) method. Then, global SST anomalies are regressed against the corrected Niño3 SST anomaly. The regressed SST anomalies are prescribed globally as the GSM boundary condition for the last two months. The interpolated global SST anomalies are used between the first and last two months.

7.6.5 El Niño prediction system

A coupled atmosphere-ocean model for monthly El Niño outlook was upgraded in July 2003. The atmospheric part was replaced by a low-resolution version (T42L40) of the one used in the current 120-day forecast system. Ocean initialization and flux corrections were also revised. The specifications of the coupled model are shown in Table 28. JMA makes the model results available through the DDB of JMA. The MOS-corrected NINO3 SST anomaly is used in the 210-day dynamical forecast.

Table 28 Specifications of the JMA coupled model

Oceanic component	Identical to the model for ODAS	
Atmospheric component	Basic equation	Primitive equation
	Domain	Global
	Resolution	T42, 40 vertical levels
	Convection scheme	Arakawa-Schubert
	Land surface processes	SiB of Sellers et al. (1986)
Coupling	Coupling interval	24 hours
	Flux adjustment	Monthly heat and momentum flux adjustment
Forecast period	18 months	
Model run interval	15 days	

8. Verification of prognostic products

8.1 Verification for short-range and medium-range prediction

Objective verification of prognostic products is operationally performed against analysis and radiosonde observations according to the WMO/CBS recommendations. Results of the monthly verification for the year of 2003 are presented in Tables 29.1 - 29.20. All the verification scores are only for the prediction from 1200 UTC initials.

8.2 Verification system for extended-range ensemble prediction

Scores of the extended-range ensemble prediction for every each season and year are shown using anomaly correlation and root mean square error for broad geographic areas. Error maps are produced for every single forecast and every each season. These are available on the Tokyo Climate Center (TCC) Web site (http://cpd2.kishou.go.jp/tcc) as listed in Table 30. Other various verification methods of reliability diagrams, relative operating characteristics, reduction rates of total loss and ranked probability score for each season are also applied.

Table 30 Verification products of extended-range ensemble prediction at TCC Web site

(a) Score

	Forecast period	Parameter	Verification areas
Anomaly correlation and root mean square error	Day 2–8, day 9–15, day 16–29, day 2–29 average	Geopotential height at 500hPa, temperature at 850hPa, sea level pressure	Northern Hemisphere (20N-90N), Eurasia (20N-90N, 0E-180E), North Pacific (20N-90N, 90E-90W), East Asia(20N-60N, 100E -179E)
		Stream function at 200hPa and 850hPa, velocity potential at 200hPa and 850hPa, and geopotential height at 500hPa	Global, Tropics(20N-20S), Northern Hemisphere(20N- 90N), Southern hemisphere(20S-90S)

(b) Map

	Forecast period	Parameter
Forecast, corresponding objective analysis, and error maps	Day 2–8, day 9–15, day 16–29, day 2–29 average	Geopotential height and anomaly at 500hPa,t temperature and anomaly at 850hPa, sea level pressure and anomaly, stream function and anomaly at 200hPa and 850hPa, velocity potential and anomaly at 200hPa and 850hPa, precipitation (forecast only)
Mean error map for each season		Geopotential height at 500hPa, temperature at 850hPa, sea level pressure

8.3 Verification system for long range ensemble prediction for 3-month outlook

Error maps for operational 120-day ensemble prediction are available on TCC in the same way as Table 30 (b). Additionally, hindcast experiments are verified by showing the scores according to the Standard Verification System (SVS) for Long-Range Forecasts (LRF) as well as the scores of anomaly correlation and root mean square error. These are also on TCC.

9. Plans for the future

(1) Cumulus parameterization scheme of RSM will be revised in early 2004.

(2) Assimilation of sea surface wind data from the QuikSCAT/SeaWinds scatterometer for the meso-scale analysis will be started in early 2004.

(3) Assimilation of precipitable water data from the SSM/I and TMI microwave imagers for the global analysis will be started in early 2004.

(4) Parameterization schemes for the gravity wave drag and atmospheric boundary layer processes of GSM will be revised in early 2004.

(5) A meso-scale non-hydrostatic model will be implemented in middle 2004.

(6) A semi-Lagrangian version of GSM will be implemented in late 2004.

(7) A 4D-VAR data assimilation system for GSM will be implemented in late 2004.

(8) The storm surge model operation will be expanded to provide predictions of storm surges caused by extra-tropical cyclones using Meso-Scale Model wind fields, whereas the present model is used only for tropical cyclone events.

(9) The grid point value products, maps and verifications for the 210-day EPS will be disseminated through the Tokyo Climate Center (TCC) Web site (http://cpd2.kishou.go.jp/tcc).

Table 29.1 Root mean square errors of geopotential height at 500 hPa against analysis (m)

Northern Hemisphere (20-90N)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	15.4	14.7	14.8	14	13.9	12	12.6	11.5	12.1	12.2	12.4	13.6	13.3
72	40.8	37.2	36.8	35	35.7	30.3	31.2	28.8	31.9	34.6	34.6	37.3	34.5
120	70.3	65.2	69.3	63.2	63.9	52.3	51.1	49.1	57.5	60	64.4	66.7	61.1

Table 29.2 Root mean square errors of geopotential height at 500 hPa against analysis (m)

Southern Hemisphere (20-90S)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	19.7	19.9	21.5	22.3	24	19.9	20.4	19.9	18.2	17.3	17.3	15.5	19.7
72	48	43.4	44.9	53.7	55	51.3	52.7	51.6	44.6	44.5	46.1	39.3	47.9
120	72.8	65.6	73.7	83.4	84.7	82.1	84.2	85.4	70.8	76.4	74	64.5	76.5

Table 29.3 Root mean square errors of geopotential height at 500 hPa against observations (m)

North America

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	14.6	14.6	14.5	14.1	13.5	12.3	11.9	10.9	11.2	12.6	13.7	15.2	13.3
72	46.5	39.3	38.9	34.9	30.9	27.2	24.9	26	29	40	40.5	41.2	34.9
120	74.7	72.9	71.6	61.3	55.4	47.3	40.3	47.4	47.4	62.9	67.4	72.9	60.1
ob. num.	79	79	77	80	80	79	79	78	80	79	79	80	79.1

Table 29.4 Root mean square errors of geopotential height at 500 hPa against observations (m)

Europe

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	22.4	18	17.1	18.2	18.2	15.6	16.2	13.6	16.6	17.2	17.2	19.4	17.5
72	46.9	41.1	40.3	38.4	33.1	25.5	24.9	26.6	35.2	38.2	36.1	43.3	35.8
120	78.3	73.3	73.3	69.4	60.2	47.2	41.5	50.2	62.2	75.2	75	84	65.8
ob. num.	55	56	56	56	56	56	55	55	56	56	56	55	55.7

Table 29.5 Root mean square errors of geopotential height at 500 hPa against observations (m)

Asia

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	15.5	14.7	14.6	15.2	16	15.2	15.2	15.5	14.7	12.6	13.6	14.3	14.8
72	31.5	28.7	29.5	33	32	30.3	25.2	24.4	29.6	25.4	26.1	30	28.8
120	51	51.8	48.8	56.9	57.5	44.5	36.5	33.1	44.8	38.1	44.7	52.5	46.7
ob. num.	47	47	48	48	48	47	47	47	47	37	41	42	45.5

Table 29.6 Root mean square errors of geopotential height at 500 hPa against observations (m)

Australia / New Zealand

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	14.3	14.7	13.3	14	13.5	12.7	13.5	11.7	13.6	12.3	11.3	12.7	13.1
72	25.5	25.5	23.7	27.5	31	25.3	30.5	26	29.4	24.3	21.6	25.9	26.4
120	43.4	38.4	37	45.4	49.9	41.9	54.1	49.7	45.8	42.1	44.2	34.6	43.9
ob. num.	22	22	22	22	23	22	23	22	22	22	22	23	22.3

Table 29.7 Root mean square errors of geopotential height at 500 hPa against observations (m)

Northern Hemisphere (20-90N)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave

24	18.5	17.1	17	16.6	16.6	15	15.4	14.1	14.8	14.9	15.4	17.1	16
72	45.4	40.4	40.1	37.6	35.4	30.7	30.6	29.3	34.2	38.7	37.7	41.7	36.8
120	76.6	71.3	72.8	69	65.4	51.6	47.4	52.1	58.3	65.2	68.2	75.4	64.4
ob. num.	233	236	236	238	241	240	240	238	242	218	222	224	234.0

Table 29.8 Root mean square errors of geopotential height at 500 hPa against observations (m)

Southern Hemisphere (20-90S)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	17.4	19.5	17.4	19.4	20.2	17.4	19.8	19.3	17.5	16	15.6	15.5	17.9
72	35.3	35.4	32.6	40.6	45.3	40.2	41.7	39.9	35	34.2	33.3	33.3	37.2
120	58.7	55.8	55	59.7	66.2	59.4	67.2	66.4	53.3	57.7	55.7	48.3	58.6
ob. num.	37	37	36	36	35	34	35	35	36	37	38	38	36.2

Table 29.9 Root mean square of vector wind errors at 250 hPa against analysis (m/s)

Northern Hemisphere (20-90N)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	5.4	5.4	5.5	5.6	5.5	4.9	5.2	5	4.9	5.1	4.8	4.9	5.2
72	11.2	10.9	10.8	11	11.6	10.9	11.1	11.1	10.9	11.1	10.1	10.7	11
120	16.8	15.7	17	16.4	17.3	16.4	15.4	15.8	16.5	17.1	16.2	16.8	16.4

Table 29.10 Root mean square of vector wind errors at 250 hPa against analysis (m/s)

Southern Hemisphere (20-90S)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	6	5.9	6.1	6.3	6.7	5.7	5.9	5.8	5.9	5.7	5.6	5.5	5.9
72	12.6	11.9	12.4	13	13.7	12.9	13.1	12.8	12.3	12.3	12.4	11.8	12.6
120	17.2	17.2	18.1	18.9	19.4	18.8	19.1	18.9	17.4	18.8	18.5	17	18.3

Table 29.11 Root mean square of vector wind errors at 250 hPa against observations (m/s)

North America

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	7.8	7.3	7.4	7.1	7.8	7	6.7	6.4	6.6	7	6.5	6.7	7
72	14.8	13.6	13.2	12.4	12.8	12.3	11	11.9	12.4	14.5	12.4	13.2	12.9
120	21.7	19.1	19.7	18.2	18.9	18	16	17.9	17.8	21.1	18.2	20.3	18.9
ob. num.	71	68	69	74	76	77	78	76	77	74	72	72	73.7

Table 29.12 Root mean square of vector wind errors at 250 hPa against observations (m/s)

Europe

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	7.7	6.6	6.9	6.8	6.6	6.7	6.9	6.3	7.2	7.3	7.5	7.1	7
72	13.9	12.3	13.2	11.6	11.3	10.8	11.5	11.9	13.4	12.9	12.2	12.9	12.3
120	20.1	19	21.4	18.2	17.5	16.8	16.1	17.6	19.2	21.7	20.3	20.2	19
ob. num.	55	55	55	55	55	55	54	55	54	54	54	53	54.5

Table 29.13 Root mean square of vector wind errors at 250 hPa against observations (m/s)

Asia

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	6.4	6.5	6.8	7.7	7.7	7.4	7.3	6.8	6.4	6.1	5.5	5.6	6.7
72	9.4	10	10.4	12	13.3	13.2	12.1	10.5	11.6	10.3	8.9	8.3	10.8
120	12.9	13.1	14	15.9	18.9	17.8	15	13.2	15.6	14.1	12.3	12.2	14.6
ob. num.	44	45	46	45	46	45	45	45	46	36	40	41	43.7

Table 29.14 Root mean square of vector wind errors at 250 hPa against observations (m/s)

Australia / New Zealand

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	7.1	6.6	6.8	7.2	7.5	6.9	6.1	6.7	6.2	6.3	6.7	6.8	6.7
72	10.5	10.2	10.7	11.3	12.2	10.6	11	9.9	10.3	10.6	10	10.2	10.6
120	13.5	13.1	15	16.9	17.8	14.9	16.6	16.1	14.9	16	14.8	13.9	15.3
ob. num.	33	33	34	34	34	34	34	33	35	34	34	34	33.8

Table 29.15 Root mean square of vector wind errors at 250 hPa against observations (m/s)

Northern Hemisphere (20-90N)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	7.2	6.8	6.9	6.9	7.1	6.8	7	6.6	6.8	6.8	6.4	6.4	6.8
72	12.9	12.1	12.1	11.9	12.2	11.9	11.9	11.9	12.5	12.9	11.4	11.8	12.1
120	19.1	17.3	18.7	17.5	18.3	17.3	16.2	17.2	17.9	19.6	17.6	18.3	17.9
ob. num.	219	219	222	228	232	233	232	231	233	207	208	209	222.8

Table 29.16 Root mean square of vector wind errors at 250 hPa against observations (m/s)

Southern Hemisphere (20-90S)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	8	7.8	7.4	7.8	8	7.2	7.2	7.4	7.1	7	7.3	7.2	7.5
72	12.3	12.1	11.9	12.7	13.5	12	12.6	11.8	11.8	11.6	11.8	11.2	12.1
120	15.7	15.7	16.5	18.6	19	17.1	18.5	18	16.3	17.7	17.3	15.4	17.2
ob. num.	43	43	43	44	43	43	43	41	43	43	43	44	43.0

Table 29.17 Root mean square of vector wind errors at 850 hPa against analysis (m/s)

Tropic

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	2.4	2.3	2.2	2.3	2.6	2.3	2.3	2.4	2.4	2.4	2.3	2.4	2.4
72	3.7	3.6	3.5	3.5	3.9	3.7	3.8	3.8	3.9	3.9	3.6	3.7	3.7
120	4.3	4.4	4.2	4.1	4.5	4.3	4.4	4.4	4.6	4.5	4.2	4.4	4.4

Table 29.18 Root mean square of vector wind errors at 250 hPa against analysis (m/s)

Tropic

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	4.9	4.9	4.7	4.8	5	4.5	4.7	4.6	4.5	4.4	4.3	4.6	4.7
72	8.1	8	7.7	7.7	8	7.3	7.5	7.3	7.3	7.5	7	7.6	7.6
120	10.2	9.5	8.9	9.1	9.8	8.8	8.9	8.6	8.7	8.9	8.4	9.3	9.1

Table 29.19 Root mean square of vector wind errors at 850 hPa against observations (m/s)

Tropic

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	4.5	4.2	4.2	3.8	4.4	4.2	4.4	4.2	4.1	4.1	4	4.4	4.2
72	5.1	4.7	4.7	4.3	5	4.8	5	4.8	4.7	4.7	4.3	5.1	4.8
120	5.6	5.3	5.1	4.8	5.4	4.9	5.3	5.2	5.2	5.2	5	5.7	5.2
ob. num.	35	36	35	34	33	32	31	33	34	34	34	33	33.7

Table 29.20 Root mean square of vector wind errors at 250 hPa against observations (m/s)

Tropic

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	6.6	6.3	6.2	6.1	6.7	6.1	6	6	6.1	6.2	6	6.5	6.2
72	8.6	8.3	8.2	7.9	8.5	7.1	7.4	7.2	7.4	7.8	7.5	7.7	7.8
120	10.1	9.9	9.3	9.3	9.8	8.8	8.4	8.3	8.4	9.1	8.8	8.9	9.1
ob. num.	34	34	33	33	33	32	31	32	33	33	33	32	32.8